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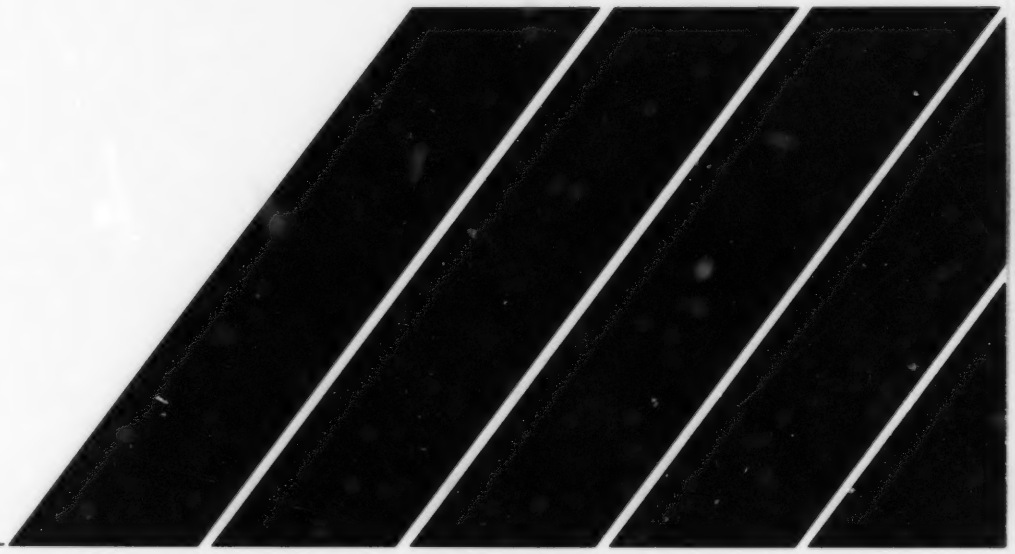
ECONOMIC ANALYSIS OF A DEMONSTRATION-SCALE ETHANOL PLANT IN GATINEAU, QUEBEC



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ECONOMIC ANALYSIS OF A DEMONSTRATION-SCALE ETHANOL PLANT IN GATINEAU, QUEBEC

PREPARED FOR:

Efficiency and Alternative Energy Technology Branch
Energy, Mines and Resources Canada
Ottawa, Ont.
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TABLE OF CONTENTS

	Page No.
Prefix	1
Introduction	2 - 3
Demonstration Plant Overview	4
Process Description	5 - 9
Plant Economic Criteria	10
Plant Investment Criteria	10 - 11
Existing Plant Valuation	11
Plant Capital & Operating Costs	
Plant Capital Cost Breakdown	12
Plant Operating Costs	13 - 15
Annual Plant Operating Cost	15
Plant Production	16
Plant Revenue	16
Investment Criteria Test	17 - 18
Summary	19
Drawing List	20
Appendix I - Layout Drawings	
Appendix II - R.O.I./Payback Graph	

RÉSUMÉ

L'objet de ce projet d'étude à l'échelle devant être menée à Gatineau est de démontrer, au moyen d'un modèle reproduisant aussi fidèlement que possible une usine à grande échelle, comment on peut obtenir des produits énergétiques (éthanol) et des produits chimiques utiles à partir de bois.

Cette étude vise à profiter des avantages économiques de la combinaison d'un projet de démonstration de production d'éthanol à partir de matière cellulosique et d'un projet d'investissement, lequel pourrait être converti en petite usine spécialisée de produits chimiques et biotechnologiques après la période d'essai, évitant ainsi la fermeture des installations comme cela a déjà été le cas d'une usine de gazéification.

Notre approche consiste à créer une usine qui, une fois le projet de démonstration d'éthanol terminé, pourrait servir à produire des enzymes à des fins de vente ainsi que des sucres de xylose et de la lignine à des fins de «remplissage». Le schéma de production sera établi de manière à garantir le plus de souplesse possible pour la production future d'autres produits.

Les critères d'investissement pour la participation du gouvernement et du secteur privé ont fait l'objet de discussions et sont inclus dans la section «critères d'investissement».

PREFIX

The purpose of the proposed scale up study at Gatineau is to demonstrate the production of energy products (ethanol) and useful chemicals from wood with as close "modelling" as possible to a major plant scale.

The mandate of this study is to access the economics of combining the demonstration of ethanol from cellulose with an investment which can be converted to a small specialty chemicals and biotechnology plant after the test period, so that it is not simply abandoned as was an earlier gasification plant.

Our approach is to have a plant which will eventually produce enzyme for sale, clean xylose sugars and lignin for filler purposes after "demonstrating" ethanol. The flow sheet will be designed to allow the greatest flexibility for future products.

The investment criteria for both Government and Private Sector participation were canvassed and are included in "Investment Criteria".

INTRODUCTION

The development of technology for converting cellulase to ethanol began in the mid 1970's. The rapidity of the advances in that science has been obscured by the precipitous drop in oil prices. This drop propelled crude oil back below its pre-crisis levels on a constant dollar basis. The present crude reference price is $18/BBL. Demand for oil is, however, increasing again and $25/BBL in constant dollars is widely anticipated for the 1990's. This assumes no special market distortions.

Techtrol's projections indicate that the declining cost for "oil equivalent" bioenergy products would be driven down by improvements in the cellulose conversion technology and would reach the current gasoline price by 1995 (basis $18/BBL). This achievement would not, however, assure market access. The Fixed investment of the gasoline companies still represents an additional hurdle of approximately $7/BBL. Our projection was that it could take ten years from now i.e. until the year 2000 for technology advances to overcome this market access hurdle.

A significant "Market Distortion" has, however, occurred. The "externalization" of pollution cost is no longer acceptable.

For the first time it now appears that the existing energy Companies may be "charged" for polluting the atmosphere or alternatively that the right to pollute will be restricted or capped. Ethanol is the only competitive CO_2 neutral fuel and hence must be a prime candidate for incorporation into gasoline so that our economic

growth is maintained. This can, however, only be a gradual process. Ethanol fuels will, we believe, first replace offshore crude and be introduced to maintain CO2 emissions at levels which meet the aims of the Toronto Conference on the Atmosphere. A major transition will take 50 years.

Canada is currently accepted as leading in Cellulose Conversion Technology. This lead has resulted mainly from the Iogen Pilot Plant. Competition from other research groups outside Canada has been reduced during the past eight years and our lead has, we believe, been maintained and expanded. . Global Warming has, however, changed the perceptions in the U.S. New environmental research exemplifies one of the prominent ways being considered to use the "Peace Dividend". Because of this we expect a massive U.S. research push in the near term. In order to maintain our lead, Iogen/Techtrol require to move ahead quickly with a demonstration plant. The lowest and most conservative cost option for the next stage of scale up is, we believe, at the small existing pulp mill in Gatineau.

DEMONSTRATION PLANT OVERVIEW

The infrastructure of the present facility at the C.P.F.P. Gatineau pilot pulp mill was designed for a 15 ODT (oven dry tons) per day pro- ype paper mill. Existing equipment in this small plant is well suited for a portion of our process and can be effectively utilized with some modification.

We prepared the attached plant layouts and integrated the existing equipment into our process utilizing all available space to its fullest. Techtrol drawings PL 1001 to PL 1004 inclusive show the layout of the proposed integrated plant for the production of wood enzyme and the wood derivative products outlined.

We propose to use the existing building for wood conditioning, cooking and separations. The extension shown is primarily dedicated to enzyme production and sugar clean up. A penthouse has been added over the enzyme fermentors for access to the top of the fermentors.

The tank area incorporated in this extension is fully enclosed and temperature maintained. The utilities added to the present plant include C.I.P. systems, chillers and compressed air. River water will be used for most cooling, treated water and high pressure steam will be purchased from the C.P.F.P.'s mill. The existing power entry will be upgraded and new additional feeders run to the mill's substation.

Product shipping will be mainly done by railcar. For this purpose existing trackage will be modified to suit.

PROCESS DESCRIPTION

Scale up of Enzyme and Sugar Production from Wood

The process block diagram (Dwg. FS-1101), shows essentially two process sections:

A) Enzyme Production Section

This area will demonstrate the production of enzymes in "full size" fermentors for in-plant use as well as future sales after the test programme is completed.

One fermentor will also be used part time to demonstrate the fermentation of both five carbon and six carbon sugars to ethanol. After the effigacy of the ethanol conversion organisms has been successfully demonstrated in a "wood" environment, we propose to phase out ethanol fermentation.

B) Sugars and Lignin Production Section

The Iogen process breaks down wood into three basic components:

- Six carbon sugar (glucose);
- Five carbon sugars (xylose);
- Lignin.

The intent in this scale up is to demonstrate ethanol production from wood on a larger scale. Our guidelines, however, require that the primary products be diverted directly to conventional markets after the test programme so that the existing plant is not a throw away investment.

A) Enzyme Production

The proposed enzyme production system consist of two - 25,000 U.S. gallon fermentors complete with the necessary peripherals. The feed chemicals for the enzyme production, will be delivered to the plant by truck and formulated at the plant into appropriate organism feed mixes for each phase of the enzyme production.

When the feed chemicals are received, they will be stored initially in sanitary tanks at an elevated temperature to prevent decay. The initial feed to the fermentor will be prepared in solution form using batch methods. This solution is next transferred through a continuous sterilizer and the temperature controlled using heat exchangers and the pH adjusted by chemical addition prior to introduction into the fermentor. The initial stage of the enzyme fermentation process is organism growth. This is carried out in a totally controlled environment of nutrients and feed with the necessary trace elements and inducers. After a highly monitored period of growth, an enzyme "production" mix of nutrients is fed to the organisms using calibrated metering pumps.

The conditions of fermentation must be carefully maintained using gas analyzers, temperature, pH and foam controllers. Since the fermentor is being continuously fed at this stage with a "production" mix including nutrients and inducers, an equivalent amount of broth must be harvested continuously into harvest tanks. Preservatives may be added to the enzyme broth in the harvest tanks depending on the rate of use of the product at the plant or the future sales requirement.

From the harvest tank, the enzyme broth is passed over a rotary vacuum filter to separate the "mycelia" or spent organisms. This mycelia is then sold to feed companies as a protein supplement for animal feed. The clarified enzyme broth is then concentrated using ultra filters and the concentrated enzyme transferred to enzyme storage tanks which must be maintained at a cool temperature. Preservatives may also be added under certain circumstances to assure a low bacterial count.

We propose that the facility will be equipped for enzyme packaging into sealed containers for outside sale after the test period.

B) Sugar and Lignin Production Section

Wood chips are pretreated with high pressure steam in two reactors. This breaks the ligno-cellulosic bonds by converting the hemi-cellulose to xylose (C5 sugars). The pretreated mix is then passed through refiners and refined to a pulp-like mash so that the xylose can be separated by washing. The residual

"pulp" is next passed over vacuum belts to wash out the xylose components and the residual ligno-cellulosic pulp transferred to the hydrolysis section in the plant.

The xylose solution is concentrated before further treatment and clarified to a clear solution prior to production of a clean xylose sugar solution. This clarification consists of neutralization with lime, settlement and removal of residual solids and then polishing using activated carbon columns to remove aromatics, colors and other similar impurities.

Techtrol Dwg. FS 1101 shows two process options at this point. One is the production of xylose products in crystalline powder form. The other is a liquid phase for intermediate term conversion of the xylose to ethanol which can be sent outside for distillation to demonstrate the production of industrial grade ethanol. Alternatively, the solution can be concentrated and sold as high quality xylose molasses or used as an animal feed.

The ligno-cellulosic solids pulp separated on the vacuum belts is re-slurried then adjusted to the correct temperature and pH balance for introduction of cellulose enzyme. After the enzyme is mixed into the slurry, the broth is pumped directly to hydrolysis tanks and held until the enzymatic reaction is complete.

After completion of the enzymatic conversion which breaks the cellulose chain links into glucose monomers, the complete broth consisting of sugar

solution and lignin is transferred to the lignin separation area. There the lignin and sugar solution are passed through vacuum belts for washing and separation. The lignin can then be dried, milled and packaged for sale. The C6 sugar solution will be tested for fermentation to ethanol initially and subsequently concentrated into molasses (C6 sugars) in multiple effect evaporators.

PLANT ECONOMIC CRITERIA

In the absence of an economic precedent for a biomass conversion plant, the major task we faced was preparation of sufficient detail for pricing. This required general layouts, equipment lists, schematics and layouts, and initial determination of equipment electric power draws, instrumentation loop requirements as well as waste and water treatment requirements.

Pricing was then done from our preliminary process engineering base. Structures were priced more conventionally on a wall area and roof span basis after spot checks and sufficient structural design for a high level of confidence. Electrical costs were estimated using the horse power and the numbers of motors. Instrumentation was estimated by unit loop cost.

PLANT INVESTMENT CRITERIA

Government Participation

The demonstration plant must be designed in such a manner that is will both demonstrate cellulose conversion at a 15 T/day level based upon reasonable assumptions, and economically survive after the test period.

Private Sector Participation

- Capital cost should include first 18 months operations as a demonstration unit.
- Plant must reach "break even" on cash flow in the first year after demonstration.
- Within 5 years of start-up, plant economics must show 10% after tax return on capitalized corporate investment including the cost of any modifications.
- Government support must be handled so that no countervail tariffs would result from the U.S. agencies.

EXISTING PLANT VALUATION

A plant value review was carried as an exercise to determine a preliminary differential between a "greenfield" plant cost and the use of the Gatineau site. This worked out to be approximately $5.4 million. A reasonable starting point for Gatineau was arbitrarily determined to be $2.7 million.

PLANT

CAPITAL & OPERATING

COST

PLANT CAPITAL COST BREAKDOWN

1989 Technology

1. Plant Capital Cost
(Appendix 1)

Buildings & Structural Supports	$968,134
Process Equipment	$12,596,794
Process Piping	$3,130,796
Electrical (including Motors)	$1,126,732
Instrumentation & Controls	$866,598
Site Services & Roads	$667,667
Engineering & Contingencies	$2,903,508
TOTAL:	$22,260,229
Interest During Construction	$2,226,023
Existing Plant Cost Allowance	$2,700,000
DRY PLANT TOTAL:	$27,186,252

2. Capitalization of Operating Cost for 18 Months

Allow Materials 1 year (Page 13)	$4,294,486.00
Labour 18 Months (1.5 x $739,720.00) (Page 14)	$1,109,580.00
Utilities 1 year (Page 15)	$1,030,300.00
Maintenance & Insurance 18 Months (1.5 x $1,157,530)	$1,736,295.00
GRAND TOTAL	$35,356,913.00

For analysis purposes allow $35 million.

PLANT OPERATING COSTS

1. Materials

Operating Supplies

Basis: 350 days/year

RAW MATERIALS	DAILY REQUIREMENT	UNIT COST	ANNUAL COST
Wood Chips	15 ODT	$65/ODT	$341,250
Lactose	11.63 Tonnes	$600/Tonne	$2,442,300
Chemicals	1.18 Tonnes	$1,587/Tonne	$655,431
Nutrients	2.11 Tonnes	$930/Tonne	$686,805
Sodium Hydroxide	0.5 Tonnes	$400/Tonne	$70,000
Sulfuric Acid	0.1 Tonnes	$70/Tonne	$2,450
Lime	2.5 Tonnes	$110/Tonne	$96,250
		TOTAL MATERIALS COST	$4,294,486

PLANT OPERATING COSTS

2. Labour

Job Description	No.	Unit Cost	Total Cost
Plant Manager	1	$50,000.00	$50,000.00
Plant Engineer	1	$48,000.00	$48,000.00
Salesmen	1	$40,000.00	$40,000.00
Clerks	2	$25,000.00	$50,000.00
Bio-Chemists	1	$48,000.00	$48,000.00
Lab Technicians	1	$30,000.00	$30,000.00
Plant Operators	6	$30,000.00	$180,000.00
Maintenance	1	$40,000.00	$40,000.00
Total Direct Labour	14 Employees		$486,000.00
Benefits 17%			$83,620.00
G & A (30% Administration 5% holidays, overtime, illness) 35%			$170,100.00
Total Labour Cost			$739,720.00

PLANT OPERATING COST

3. Utilities

Steam	103,000 lbs.	$6.00/1000 lbs.	$216,300
Power	40,800 kWh	0.05/kWh	$714,000
Water	Allowance		$100,000
TOTAL			$1,030,300

4. MAINTENANCE & INSURANCE

Maintenance 3.2% of Capital Cost	$712,330
Insurance & Taxes 2% of C. Cost	$445,200
TOTAL	$1,157,530

ANNUAL PLANT OPERATING COST

1.	**Labour**	**$739,720**
2.	**Materials**	**$4,294,486**
3.	**Utilities**	**$1,030,300**
4.	**Maintenance & Taxes**	**$1,157,530**

PLANT PRODUCTION

Molasses		
Glucose Base Products	2,250.0	Tonnes/year
Xylose Base Products	1,120.0	Tonnes/year
Total Molasses	3,370.0	Tonnes/year
Raw Lignin	1550.0	Tonnes/year
Enzyme	10.0	MML/year

PLANT REVENUE

(Full operations)

	ANNUAL PRODUCTION	SELLING PRICE	ANNUAL REVENUE
Enzyme	10.0 MML/year	$0.98/Litre	$9,800,000
Lignin	1,550 Tonnes	$240/Tonne	$372,000
MOLASSES			
Glucose	2,250 Tonnes	$200/Tonne	$450,000
Xylose Products	1,120 Tonnes	$200/Tonne	$224,000
		TOTAL:	$10,846,000

INVESTMENT CRITERIA TEST

Basis: **Capital Cost of $35,000,000.00 (allowance).**

1. **Break even in cash flow during first year after "Demonstration" is complete.**

   Assumption: 30% of Plant Capacity Sold

Revenue

30% of $10,846,000 (Page No. 16)	$3,253,000.00

Out of Pocket Costs

Materials 30% of $4,294,486 (Page No. 13)	$1,288,345.00
Labour 100% (Page No. 14)	$739,720.00
Utilities 30% of $1,030,000 (Page No. 15)	$309,090.00
Insurance & Taxes 100% (Page No. 15)	$445,200.00
Maintenance (inc. start-up) 75% (Page No. 15)	$534,247.00
TOTAL	$3,316,620.00

Criteria 1 Satisfied

INVESTMENT CRITERIA TEST

2. Provide a 10% after tax return on capitalised Private Sector investment after 5 years following start-up.

Annual Operating Cost (Page No. 15)	$7,222,036.00
Annual Revenue (Page No. 16)	$10,846,000.00
Spread Applicable to Capital Return	$3,623,964.00
[Back Calculation]	
Total Capitalised Investment for 10% After Tax Net (Payback 4.72 years - see Appendix III)	$17,105,110.00
Investment Current Basis Discounted at 15% for 5 years)	$8,504,263
Indicated Cost Share to Meet by Investors	$8,504,263

Approximately 25%

SUMMARY

Our economic analysis of the Gatineau Plant highlights the dominant necessity of enzyme sales to meet the financing criteria for on-going plant viability. This could play out in two ways. The first is a developing requirement for enzyme in a future ethanol business as research drives overall requirement down. The second is the potential for intermediate term enzyme sales into the pulp and paper industry for pollution control.

We anticipate that, within the term of the analysis (5 years), the two fermentors will serve a 1500 tonnes/day ethanol plant. The Gatineau Plant could hence serve a useful future role as an adjunct to the major next step "scale up". In that scenario, the 15 tonne capacity would initially represent a standard "scale up" step of a factor of 10 from the existing pilot plant but produce enzyme for the next major "demo" scale up and the first production size plant as enzyme requirement drops. Alternately, a developing market for xylanese enzyme for AOx abatement in the pulping industry could also make the overall investment viable.

The risk inherent in these scenarios will be compared by investors to a 150 tonne/day ethanol plant which could result in ethanol costs below current grain and fulfill the next stage in demonstration prior to a major production plant. In the event that the oil prices continue to be depressed and the Government does not impose stricter CO_2 regulations, the Gatineau Plant would be a logical step to be followed by a large scale ethanol demonstration plant when conditions warrant. If oil prices should rise or carbon taxes be enacted, the second plant could then quickly follow Gatineau.

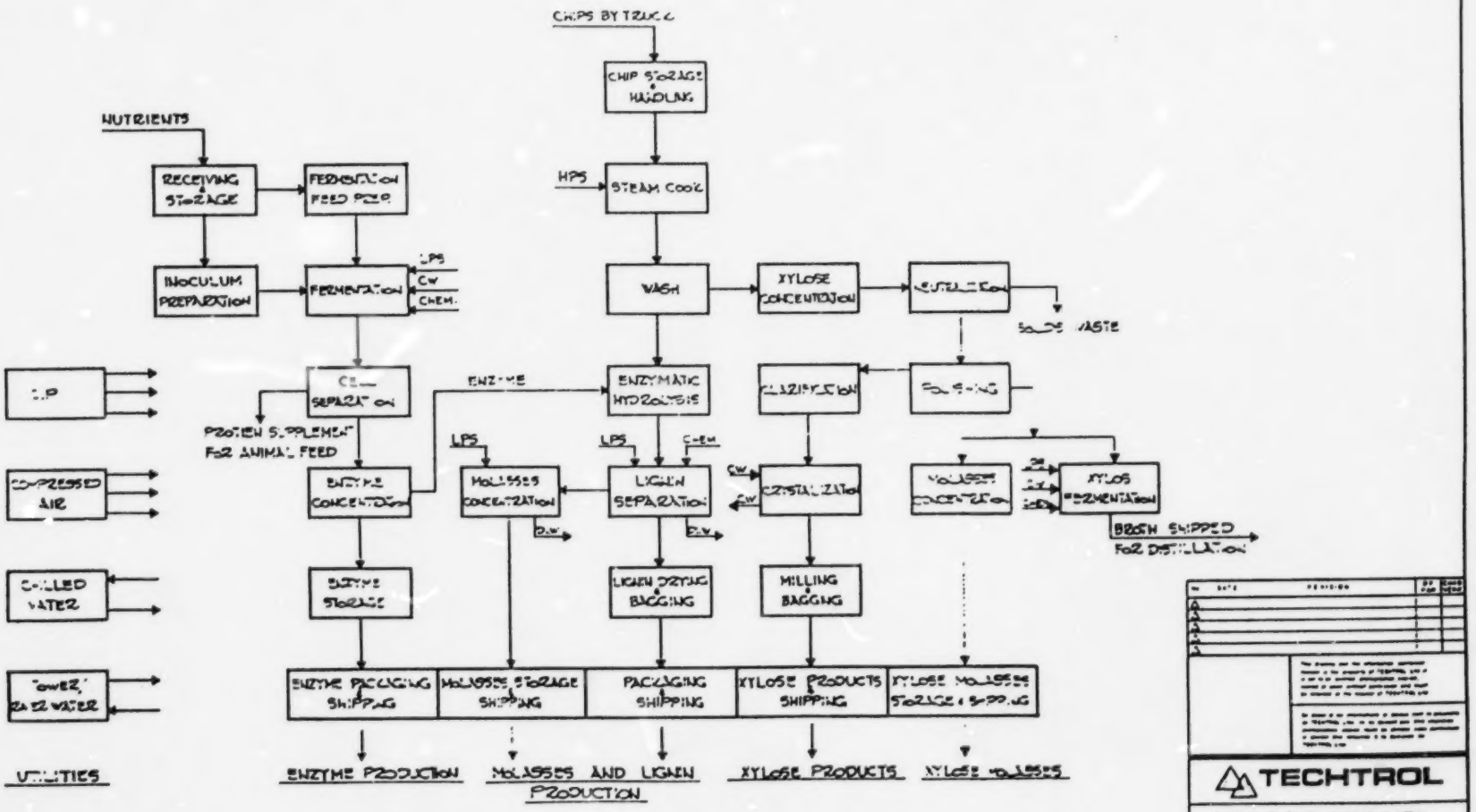
We believe that the Gatineau Plant approach is "saleable" based on a shareholder contribution of approximately 25% as outlined.

DRAWING LIST

Drawing No.	Title
FS-1101	Demo Plant - Overall Block Diagram Plant
PL-1001	Demo Plant - Plant Layout Ground Floor
PL-1002	Demo Plant - Plant Layout 2nd Floor Plan
PL-1003	Demo Plant - Plant Layout 3rd Floor Plan
PL-1004	Demo Plant - Plant Layout Elevation
SK-101	C.I.P.'s Pilot Pulp Mill - Ground Floor Plan
SK-102	C.I.P.'s Pilot Pulp Mill - Floor @ EL 187'-0"
SK-103	C.I.P.'s Pilot Pulp Mill - Floor @ EL 202'-0"
SK-104	C.I.P.'s Pilot Pulp Mill - Elevations

APPENDIX I

LAYOUT DRAWINGS



OVERALL DEMO PLANT BLOCK DIAGRAM

TECHTROL

DEMO PLANT - IOGEN LTD.

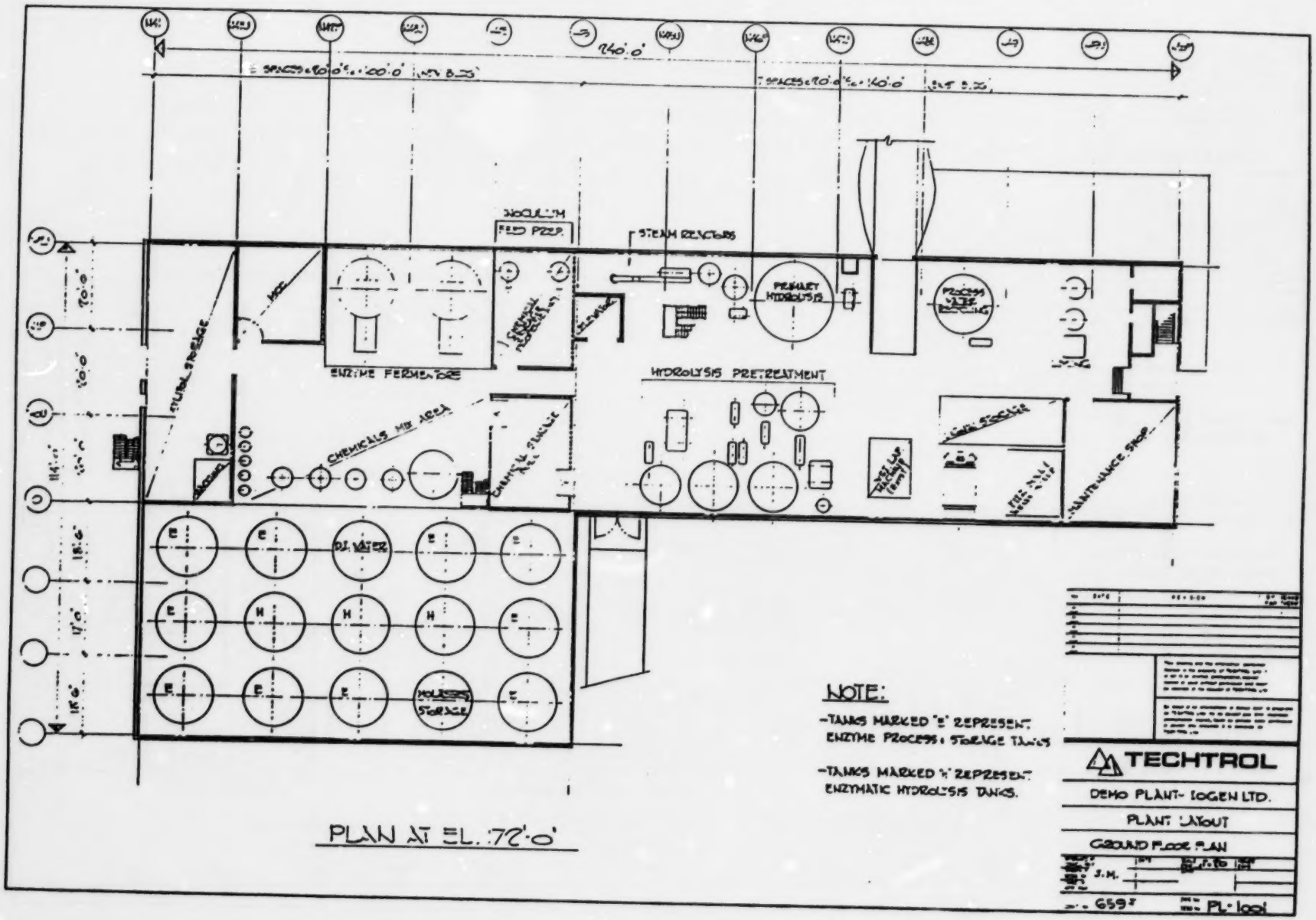
MOLASSES ETHANOL PRODUCTION

OVERALL BLOCK DIAGRAM

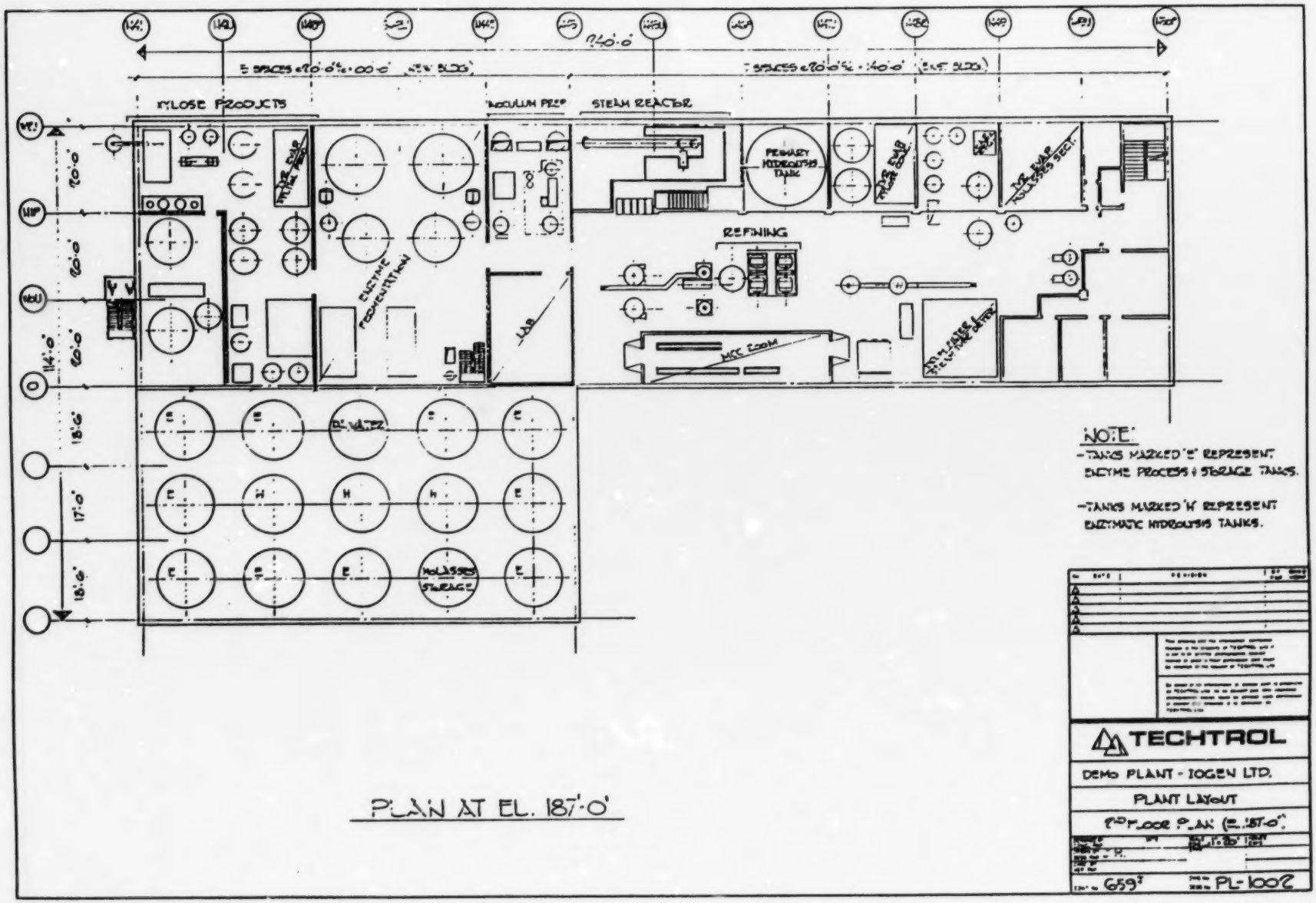
J.M.

6:9:

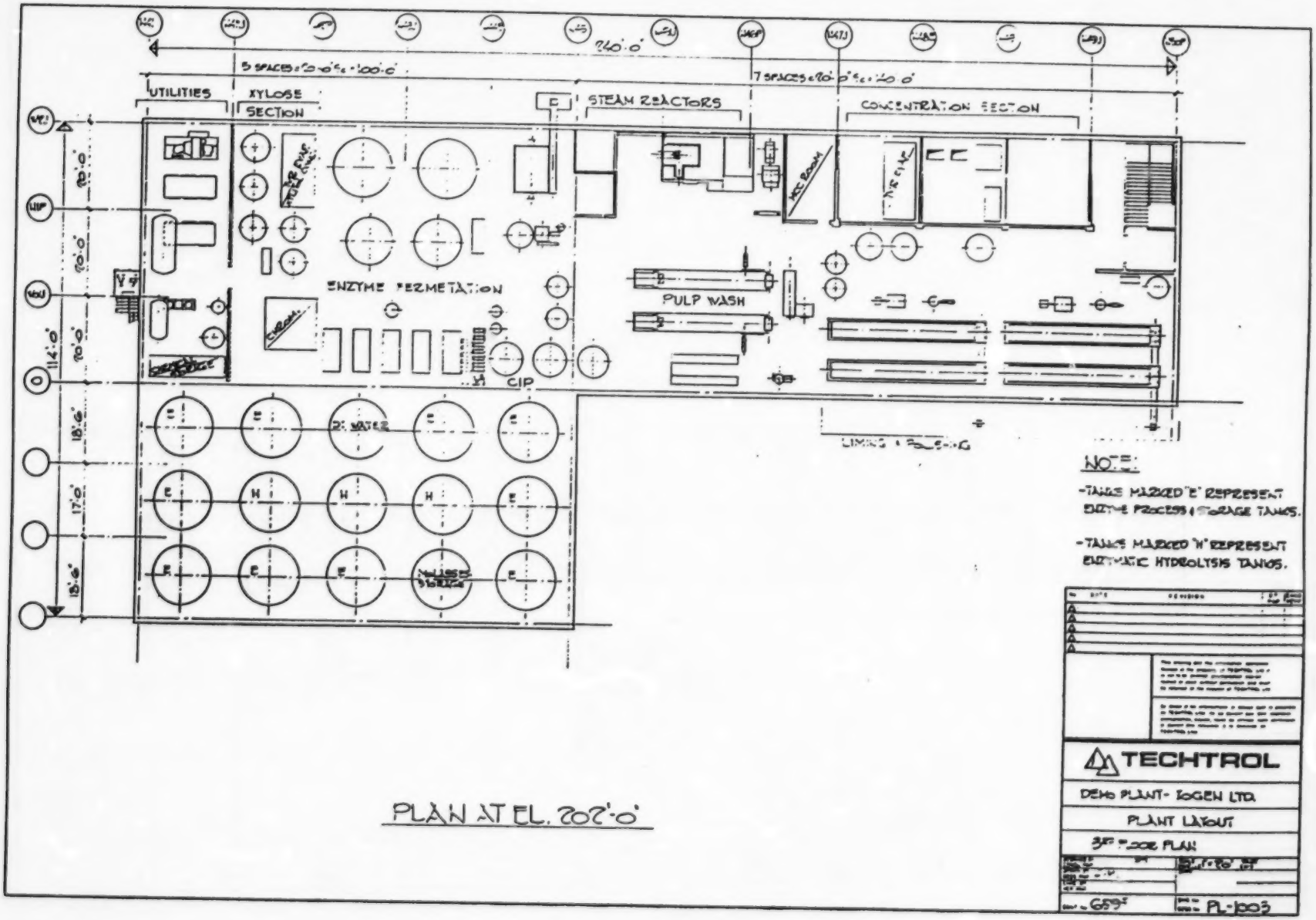
PS-1101



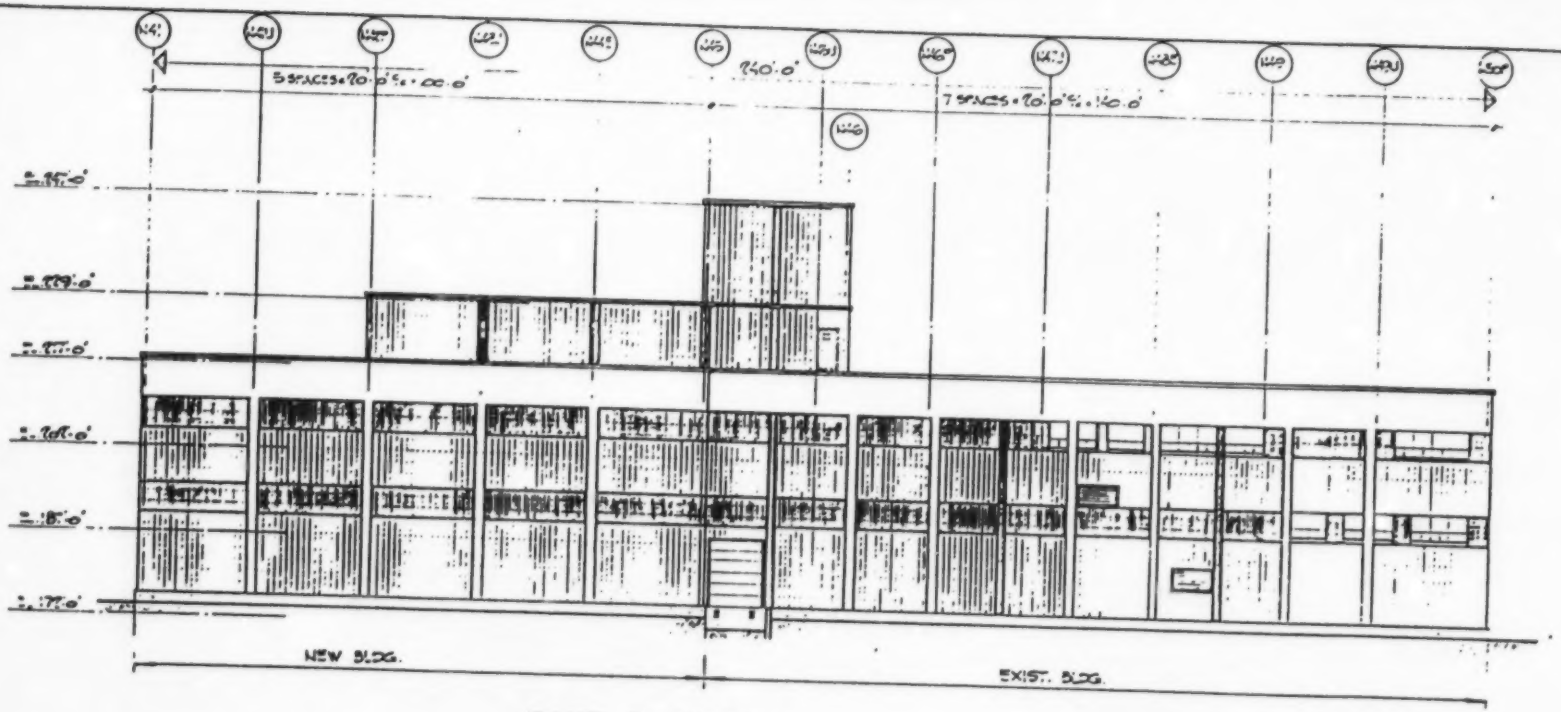
PLAN AT EL. 72'-0"



PLAN AT EL. 187'-0'



PLAN AT EL. 202'-0"



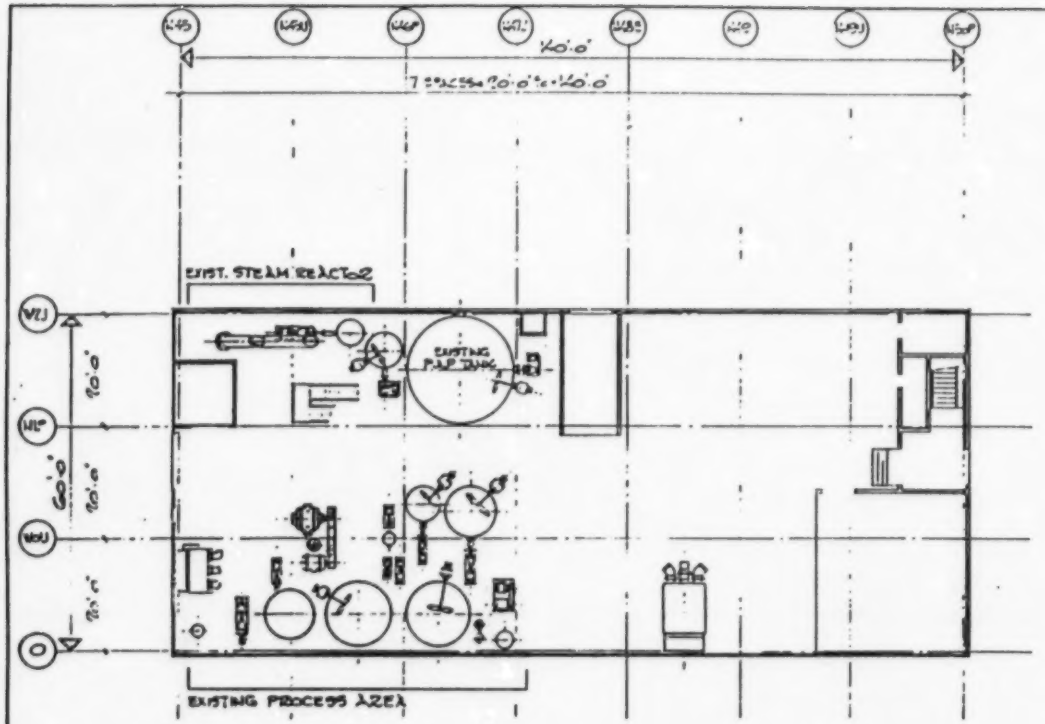
EAST ELEVATION

TECHTROL

DEMO PLANT - LOGEN LTD

PLANT LAYOUT

ELEVATION



PLAN AT EL. 17'-0"

EXISTING FLOOR PLAN @ CIP's GATINEAU PILOT PULP MILL

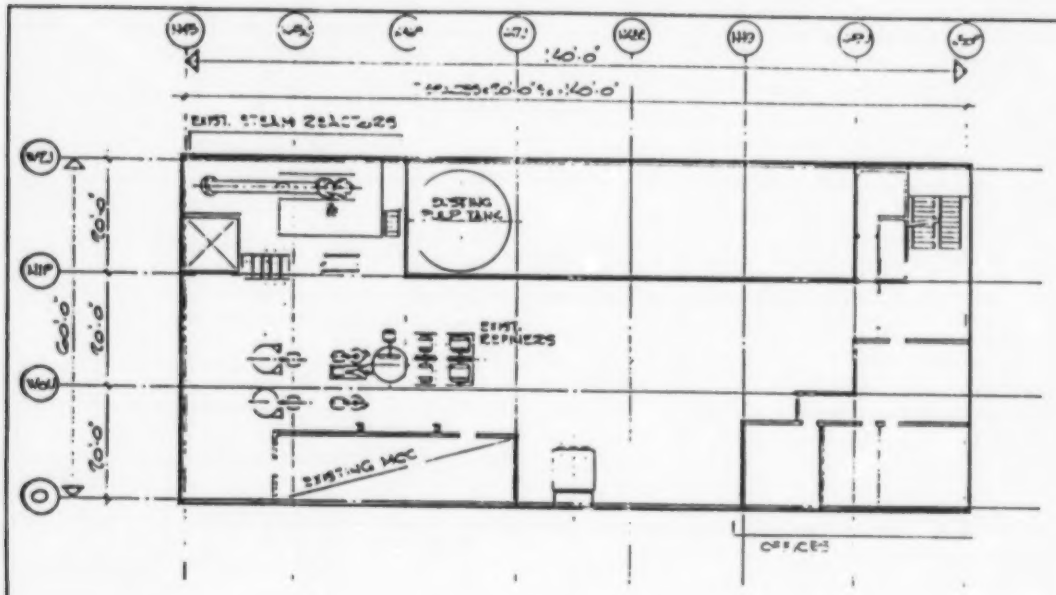
TECHTROL

DEMO PLANT - IOGEN LTD

CIP's PILOT PULP MILL

GROUND FLOOR PLAN

759 SK-101



PLAN at EL. 87'-0"

EXISTING FLOOR PLAN of CIP's GATINEAU PILOT PULP MILL

TECHTROL

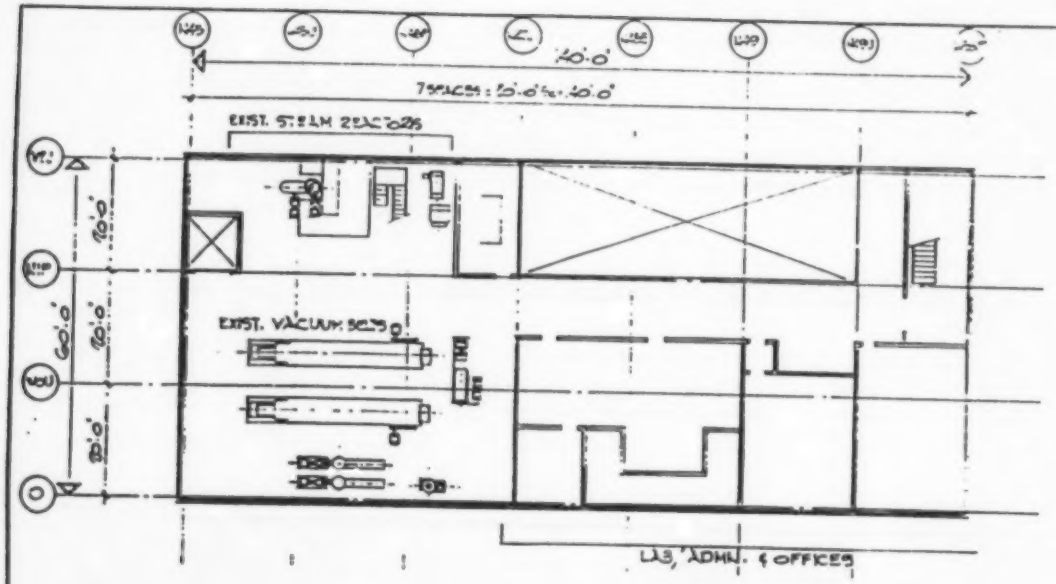
DEMO PLANT - IOGEN LTD.

CIP's PILOT PULP MILL

FLOOR PLAN AT EL. 87'-0"

759

SK-102



PLAN AT EL. 202'-0"

EXISTING FLOOR PLAN & CIP's GATINEAU PILOT PULP MILL

TECHTROL

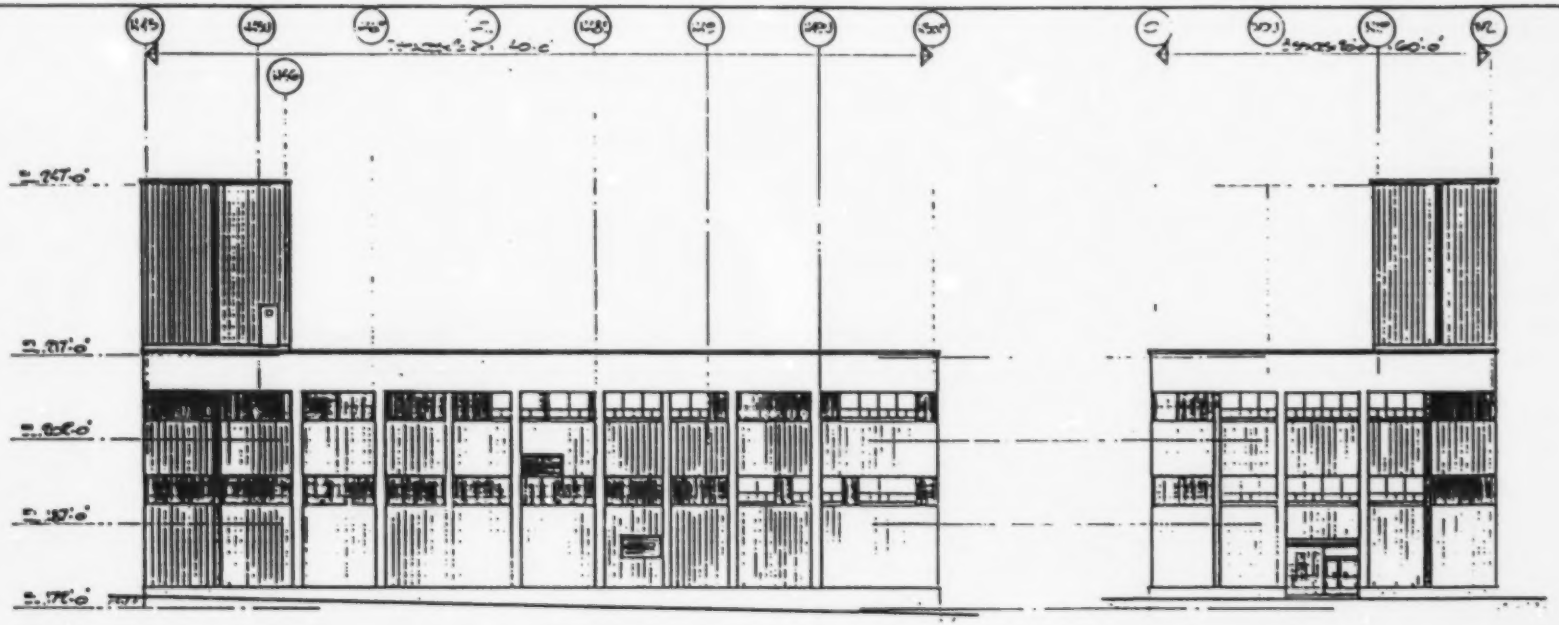
DEMO PLANT - OGEN LTD.

CIP's PILOT PULP MILL

FLOOR PLAN AT EL. 202'-0"

SCALE: 3/32" = 1'-0"

DWG. NO. 96-103



EAST ELEVATION

NORTH ELEVATION

EXISTING BLDG. ELEVATION c CIP's GATINEAU PILOT PULP MILL

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DEMO PLANT - OGDEN LTD.

CIP's PILOT PULP MILL

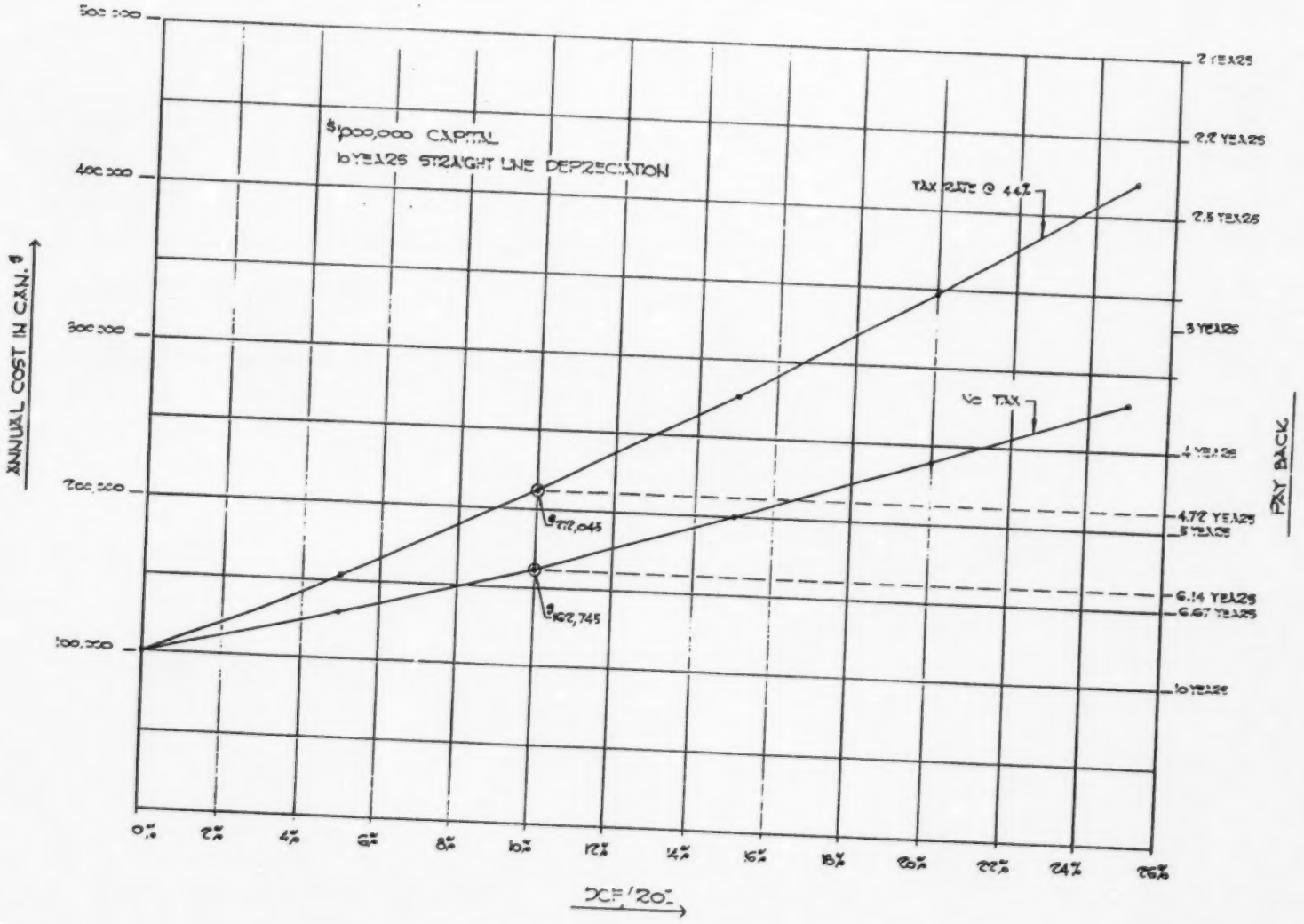
ELEVATIONS

SK-104

APPENDIX II

R.O.I./PAYBACK GRAPH

RETURN ON CAPITAL CURVE



TECHTROL LTD./FIG.1